Lecture 11
Feb 22, 2005

Lab Makeup

- This week is Lab Makeup Week
  - It is critical you makeup any of the labs you missed so far. **You are expected to complete all laboratory experiments in order to get a passing grade for the course** (see more details in syllabus).
  - If you have done all the first six labs, you get a break from lab this week.

The skinny tires of a 10-speed racing bicycle require more air pressure than the fat tires on an equally massive mountain bike because
A. the racing bike moves faster.
B. the area of contact of the racing bike's tires is greater than that of the bike with fat tires.
C. the racing bike touches the ground over a smaller area than the bike with fat tires.
D. the racing bike exerts more force on the ground.

It is observed that as bubbles rise in a deep column of water, the diameter of the bubbles increases. This is best explained by
A. Bernoulli's Principle. B. Archimedes Principle C. Boyle's Law. D. Pascal's Principle.

Archimedes Principle states that
A. the pressure in a fluid is directly related to the depth below the surface of the fluid.
B. an object immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid.
C. the pressure of a fluid is inversely proportional to the temperature of the fluid.
D. the velocity of a fluid is directly proportional to the pressure exerted on the fluid.

The density of ice is about 900 kg/m^3, and the density of water is about 1000 kg/m^3.
A cubic block of ice one meter on a side floats in water. Assuming that the lowest square face of the cube is horizontal, the height of the block above the water line is:
A. 0.1 m. B. 0.2 m. C. 0.5 m. D. 0.8 m. E. 0.9 m.

Learn:
1. The definition of temperature T and heat Q and how to distinguish between them.
2. The definition of specific heat capacity, latent heats and the calorie.
3. The definitions of Farrenheit, Celcius and Kelvin temperature scales.
4. The first law of thermodynamics.
5. The equation of state for an ideal gas.
6. The distinction between conduction, convection and radiation as methods of heat transfer.

Understand:
1. How to measure T and how to express the results on the three T scales.
2. How the difference in specific heat of substances leads to different T changes for a given amount of heat transfer.
3. How the latent heats are involved in changes in state.
4. How to use the first law of thermodynamics.
5. How heat transfer is achieved in the processes of conduction, convention, and radiation.

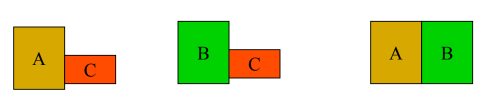
Thermodynamics

- Thermodynamics is the study of heat and its effects on matter. Its focus is the concept of energy transfer between a system and its environment and the resulting temperature variation.
- This science was developed during the 1800's to explain how steam engines converted heat into work.
- Thermodynamics ultimately extends the energy conservation principle to include the effects of heat.

Heat

- The energy exchanged between objects because of temperature differences is called **heat**.
- Objects are in **thermal contact** if energy can be exchanged between them.
- **Thermal equilibrium** exists when two objects in thermal contact with each other cease to exchange energy

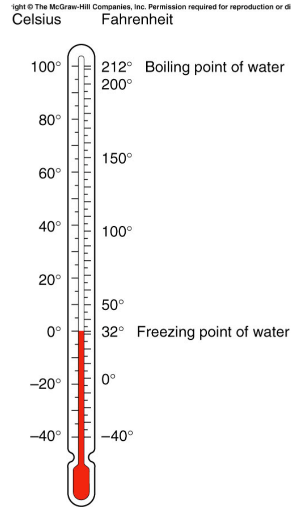
Zeroth Law of Thermodynamics

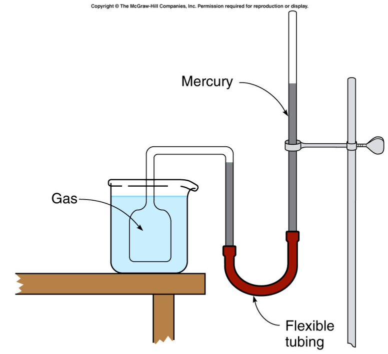


- If objects **A** and **B** are in thermal equilibrium with a third object **C**, then **A** and **B** are in thermal equilibrium with each other.
- Allows a definition of temperature since object C could be a thermometer

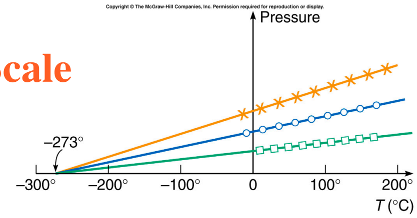
Temperature
from the Zeroth Law of Thermodynamics

- Two objects in thermal equilibrium with each other are at the **same temperature**.
- **Temperature** is the property that determines whether or not an object is in thermal equilibrium with other objects.





Kelvin Scale



- All gases extrapolate to the same temperature at zero pressure
- This temperature is absolute zero
- This temperature is called absolute zero
- This is the zero point of the Kelvin scale = 0 K

Temperature Scales (I)

- Thermometers can be calibrated by placing them in thermal contact with an environment that remains at constant temperature.Environment could be
  - mixture of ice and water in thermal equilibrium
  - water and steam in thermal equilibrium
- There are three major scales of temperature

Kelvin, Celsius, Fahrenheit

Temperature Scales (II)

- Other non-absolute scales which are used are Fahrenheit and Celsius, both of which use phase changes of water as reference points
- Celsius: Water freezes at 0 and boils at 100
- Fahrenheit: Water freezes at 32 and boils at 212.

$$T_C = \tfrac{5}{9}(T_F - 32)$$
$$T_F = \tfrac{9}{5}T_C + 32$$
$$T_K = T_C + 273.2$$

Absolute Zero

- Temperature is a measure of the kinetic energy of the molecules in matter.
- Absolute zero is the temperature at which molecules have no kinetic energy.
- The Kelvin scale measures temperature from absolute 0

Absolute zero = 0 K = -273.2 C = -459.7 F

Effects of Heat on Solids and Liquids

- Solids and liquids are incompressible which means that changes in pressure and temperature do not alter their volume very much
- Solids and liquids are, however, subject to a small amount of thermal expansion.
  - Thermal expansion=volume increases with temperature
- As the temperature increases, solids either melt or sublimate; Liquids boil.

Specific Heat Capacity

- The specific heat capacity is the amount of heat required to raise a unit mass of the material by a unit amount of temperature (1 g by 1C).
- The units of specific heat capacity are:

$$\frac{\text{cal}}{\text{g C}}$$

c=1.0 for water, 0.49 for ice, 0.11 for steel, 0.58 for alcohol, 0.0305 for lead

- The amount of heat (Q) required to raise a mass of substance (m) with specific heat capacity (c) by a temperature (ΔT) is:

$$Q = m\ c\ \Delta T$$

Latent Heat

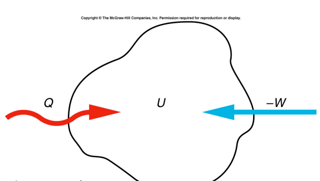
- When a substance undergoes a phase change, there is a change in internal energy.
- This change is called the latent heat.
- The heat required to melt a solid is called the latent heat of fusion. $Q = m\,L_f$
- The heat required to boil a liquid is called the latent heat of vaporization. $Q = m\,L_v$

Latent Heat of Water

- The latent heat of fusion for water is 334,000 J/kg = 80 cal/g
- The latent heat of vaporization in water is 2,260,000 J/kg = 540 cal/g
- For example, let us suppose that we have a pot filled with 1 kg of ice at -10ºC and put it on a stove which delivers heat at a rate of 200W. How long does it take to boil all the water?

(1cal=4.186 J)

First Law of Thermodynamics



- Heat is a form of energy
- The First Law of Thermodynamics:

The change in internal energy of a substance equals the work done on it plus the heat transferred to it

$$\Delta U = Q - W$$

U=internal energy
Q=heat
W=work